# APPENDIX 2

# Gravel Mining and Scour of Salmonid Spawning Habitat in the Lower Stanislaus River

by

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## INTRODUCTION

A stock-recruitment analysis of fall-run Chinook salmon (*Oncorhynchus tshawytscha*) escapement in the lower Stanislaus River suggests that spawning and/or rearing habitat in the river limits population recruitment during years when streamflows are adequate (Appendix 3). A geomorphic analysis of the river by Kondolf and others (2001) indicates that the fish habitat in the lower Stanislaus River has been degraded by the loss of gravel recruitment and riparian encroachment after the construction of upstream dams, particularly New Melones Reservoir in 1979 and by instream gravel mining. As a result of accelerated rates of streambed scour caused by riparian encroachment and the construction of dikes to isolate the floodplains for agriculture prior to 1970, many of the 136 spawning areas identified in October 1995 in the historical spawning reach between Goodwin Dam and Riverbank were armored or compacted (CMC and others 1996). Other areas of the river, including spawning riffles in the active channel, were mined for gravel and gold with drag lines primarily between 1940 and 1970 (P. Frymire, personal communication, see "Notes"). The mined areas currently consist of long, deep ditches and large ponds that primarily provide habitat for predators, such as striped bass (*Morone saxatilis*), Sacramento pikeminnow (*Ptychocheilus grandis*), largemouth bass (*Micropterus salmoides*), and smallmouth bass (*M. dolomieui*).

This report identifies the spawning areas that were either substantially scoured or mined in the lower Stanislaus River to aid future fishery studies and restoration planning. By identifying whether fishery data were collected in mined or unmined areas, the benefits of potential restoration actions can be evaluated for the Stanislaus River. For example, the riffles in the unmined areas were usually well used by spawning salmon in fall 1994 and 1995 compared to the riffles that remain in the mined reaches. One possible explanation is that although riparian encroachment since the construction of New Melones Reservoir in 1979 and pre-1970 dike construction have accelerated the scour of gravel from spawning riffles, gravel that is scoured from the riffles in the unmined reaches provides recruitment for the downstream riffles. Over time, the upstream most riffles in the unmined reaches typically became degraded whereas the downstream riffles usually contain abundant gravel and still function as high quality spawning and rearing habitat. Conversely, the riffles in the mined reaches are typically isolated between ditches or ponds, and so the gravel is scoured away during high flows due to the absence of recruitment.

## METHODS

The salmon spawning riffle maps of the lower Stanislaus River between Goodwin Dam and Jacob Meyers Park in Riverbank that were made by the California Department of Fish and Game (CDFG) from aerial photographs and field surveys taken between 1958 and 1964 and revised in 1972 (CDFG 1972) are presented here as evidence of instream gravel mining (Maps 1-6). These maps clearly show that the long ditches, 100 to 160 feet wide, and large in-river pits were a product of mining operations as indicated by the presence of dredger tailings and "old drag lines" adjacent to some of the ditches and pits shown on the maps. The maps also show that in the areas that were not mined, the channel was relatively narrow, 60 to 80 feet wide, and there were high densities of spawning riffles, many of which were still present during fall 1994 and 1995 surveys by Carl Mesick Consultants and others (CMC and others 1996).

These maps also provide evidence that most if not all of the gravel has been scoured from some of the riffles. The CDFG maps show the exact location and size of spawning riffles present between 1958 and 1972, whereas some of them contained very little or no gravel during the mid-1990s CMC surveys (CMC and others 1996). The formation of new riffles present during the CMC surveys but not shown on the CDFG maps also indicate that gravel was scoured from nearby upstream riffles.

The CDFG maps attached with this report were reduced in size by about 60% and the area of each spawning riffle was re-marked in bright red. The spawning riffles that were present in both the 1958-1972 surveys and the 1994-1995 surveys were identified according to the numbering system used by Carl Mesick Consultants (CMC and others 1996).

Although the CDFG (1972) table with the length of each spawning riffle, including potentially reclaimed habitat, is included in this report, neither the number of riffles nor the size of the riffles drawn on the maps corresponded to the information in the table. For example, there are seven distinct riffles shown in the Goodwin Canyon reach in Map 1, however, only three riffles are listed in the table for this reach. Similarly, the second riffle downstream from the Knights Ferry Bridge is listed as 205 feet long, whereas the second riffle downstream from the covered Knights Ferry Bridge (R2) is shown as being very short on Map 2. Therefore, no comparisons were made between the CDFG (1972) data and the length of riffles measured by CMC between 1994 and 2000.

## RESULTS

**A) Goodwin Canyon** (Rivermile 58.5 to 54.7, Goodwin Dam to the Covered Bridge, Map 1)

Instream Gravel Mining:

1) There is a large deep pool just downstream from Goodwin Dam and the foot bridge shown in Map 1. This pool is unnaturally deep and probably resulted from mining. CDFG added gravel with a helicopter to this site in 1997.
2) The 100-meter-long area immediately upstream from Riffle TMA is unnaturally deep and wide and was probably mined. The Two-Mile Bar floodplain was lightly mined prior to 1980. CMC added 470 cubic yards of gravel to Riffle TMA in 1999.

Scour:

1) Map 1 shows Riffle TM1 to be relatively large and extending downstream in both the right and left channels along an exposed mid-channel bar. In 1994 and 1995, most of the spawning-sized gravel was confined to a 20-foot-long by 100-foot-wide bar upstream of the mid-channel bar (Figures 5 and 21 in CMC et al. 1996); the downstream right and left channels adjacent to the mid-channel bar were armored and lacked spawning-sized gravel. In 1998, about half of the spawning-sized gravel that was present in 1994-1995 at Riffle TM1 had been scoured away, presumably by the spring 1997 high flows. Two-Mile Bar has not flooded since at least 1980 due to berms created for mining.
2) With the exception of riffles TM2 and TM3, most of the gravel has been scoured from the riffles in Goodwin Canyon.
3) CDFG added gravel to Riffles DFG1 and DFG2 in summer 1997; however, much of the new gravel was scoured away from both sites by fall 1999.
4) The lowermost 1.5 miles of Goodwin Canyon consists of long, deep pools separated by high gradient cascades that are well scoured due to the confined nature of the lower canyon.

Riffle density in 1972: Nine riffles in the upper 2.5 miles (3.6 riffles/mile).

**B) Knights Ferry** (Rivermile 54.7 to 53.5; Old Covered Bridge to Riffle R10, Map 2)

Instream Gravel Mining:

1) The approximately 50-meter-long area immediately upstream from the Knights Ferry County Bridge is unnaturally deep and wide and so it appears to have been mined. The 1937 and 1957 aerial photos (Kondolf and others 2001) show this location (riffles R1 and R2) to be a narrow channel. Perhaps the channel was widened when the bridge was constructed in 1987.
2) Although the large point bar adjacent to riffles R5 to R9 was developed for gravel mining, the shallow, narrow channel suggests that no in-river mining occurred in a majority of this reach.

Scour:

1) Since 1937 and perhaps 1957, most of the riffles in the 0.65 mile-long reach downstream from the Knights Ferry County Bridge built in 1987 have been almost completely scoured away. The four riffles in this reach observed in 1995 (riffles R2A to R4) were small and poorly used by spawning salmon in fall 1994 and 1995. The floodplain was isolated from the river by gravel that was deposited in the encroaching vegetation just downstream of Riffle R2.
2) Although scour has undoubtedly occurred at the five riffles (R5 to R10) in the downstream most 0.4-mile-long reach in this section, most were well used by spawning salmon in fall 1994.

Note: Although the riffle immediately downstream of the Old Covered Bridge at the upstream boundary of this reach was not identified in the CMC 1994-1995 surveys, this riffle was present and used by spawning salmon in fall 1999 and 2000.

Riffle density in 1972: Nine riffles in 1.2 miles (7.5 riffles/mile).

**C) Lovers Leap** (Rivermile 53.5 to 51.6; Riffles R11 to Willms Pond, Map 2)

Instream Gravel Mining:

1) There are two small in-river mine pits near the Lava Cliffs between riffles R10 and R12 shown in Map 2. Riffle R11 is an 80-foot-long riffle (not shown on Map 2) that separates these pits.
2) Map 2 shows two isolated pits near the Ohe Sand and Gravel Quarry where riffles R14 and R14A exist today; the river has since captured these pits.
3) The CDFG map shows that a berm prevented flow through the lower half of Willms pond prior to 1972; Map 2 shows no spawning habitat in the natural channel to the north of Willms Pond although water was flowing through the lower half of this natural channel.
4) Western Sand and Gravel worked with the Ohe Sand and Gravel Quarry to mine almost all of the gravel in this reach until about 1980. The channel was widened to 100 to 160 feet and the bed was excavated to 6 to 10 feet deep.

Scour:

1) Almost all of the gravel has been scoured from riffles R13 and R17, which are shown to be quite large in Map 2. The gravel scoured from R17 probably formed Riffle R19, which was augmented with more gravel by CMC in 1999.

Riffle density in 1972: Five riffles in 1.9 miles (2.6 riffles/mile).

**D) Below Willms Pond** (Rivermile 51.6 to 51.1; Riffles R21 to R26A, Map 2)

Instream Gravel Mining:

There is no evidence of gravel mining in this reach. There are two separate, narrow channels that are highly encroached with mature woody vegetation. Most of the spawning habitat is in the north channel although a few salmon spawned in the south channel in fall 2000.

Scour:

There is abundant spawning-sized gravel at the riffles in the middle of this reach, but not at riffles R21, R22, R26 and R26A. All of the riffles observed in 1972 were still present in 1994 and 1995.

Riffle density in 1972: Six riffles in 0.5 miles (12.0 riffles/mile).

**E) Horseshoe Road** (Rivermile 51.1 to 49.75; Riffles R27 to R29, Map 2)

Instream Gravel Mining:

1) Map 2 shows the presence of "Dredge Tailings" and an "Old Drag Line" in the Horseshoe Road Park area. The channel is unusually wide and deep immediately downstream from Riffle R26A to Riffle R29 at Honolulu Bar. Riffle R27 was augmented with gravel from the Merced River in 1994 by CDFG and the Department of Water Resources.

Scour:

1) No data to assess scour: Riffle R28A is shown as a small riffle in 1972 and it was quite short in 1998 before gravel was added by CMC.

Riffle density in 1972: Three riffles in 1.35 miles (2.2 riffles/mile).

**F) Honolulu Bar** (Rivermile 49.75 to 48.5; Riffle R29 to R37A, Maps 2 and 3)

Instream Gravel Mining:

1) Although there are dredger tailings on the south bank in this reach, the gravel was probably obtained from either the channel upstream of Riffle R29 or from the pit on the nearby Ardis property. There is no evidence of gravel mining in the channel as it was relatively narrow (60 feet wide at Riffle R32) and contained abundant gravel during the CMC surveys. There was also a dense, mature, woody riparian forest until the area burned in 1999. This area was well used by spawning salmon in 1994 and it is also reported to provide good trout fishing.

Scour:

1) There was no evidence of degradation at Riffle R32, which was measured to be about 100 feet long with abundant spawning-sized gravel in fall 1995. All riffles in this reach that were present in 1972 were identified during the 1994 and 1995 surveys. However, a foot survey in summer 1999 suggests that a substantial amount of gravel has been scoured from the riffles in this reach by the 1997 high flows.

Riffle density in 1972: Nine riffles in 1.25 miles (7.2 riffles/mile).

**G) Above Orange Blossom Bridge** (Rivermile 48.5 to 47.4, Riffles R38 to R40, Map 3)

Instream Gravel Mining:

1) Map 3 shows "Dredge Tailings" at two locations in this reach.
2) The channel is relatively wide at most locations in this reach.

Scour: No data

Riffle density in 1972: One riffle, R39, in 1.1 miles (0.9 riffles/mile).

**H) Below Orange Blossom Bridge** (Rivermile 47.4 to 44.9, Riffles R40 to R57, Maps 3 and 4)

Instream Gravel Mining: There is no evidence of instream gravel mining in this reach

Scour: All of the riffles shown in the CDFG maps were still present during the CMC surveys. Furthermore, salmon were spawning in all but one of these riffles during the 1994 CMC survey.

Riffle density in 1972: Seventeen riffles in 2.5 miles (6.8 riffles/mile).

**I) Valley Oak Recreational Park to Jacob Meyer Park, Riverbank** (Rivermile 44.9 to 33.8, Riffle R58 to R105, Maps 4, 5, and 6)

Instream Gravel Mining:

1) Although there are areas that were obviously mined for gravel (e.g., the large pit at the Oakdale Recreational Area), the CDFG maps do not provide sufficient detail to distinguish between all the mined and unmined areas.

Scour:

1) Fifteen of the 40 riffles on the CDFG maps were not present during the CMC surveys suggesting that a substantial amount of gravel was mobilized in this reach. For example, there is a large gravel bar in the upstream end of the large pit at the Oakdale Recreational Area that was not shown on the CDFG maps. Presumably, the gravel in this bar was scoured from the upstream riffles (R76-R78).

## SUMMARY

The following table presents the estimated amount of habitat that was mined in different reaches of the lower Stanislaus River based on an evaluation of the 1972 CDFG riffle maps and the CMC and others spawning surveys in 1994 and 1995.

| Reach | Percentage Mined | Spawning Riffles/Mile in 1972 |
|---|---|---|
| Upper Goodwin Canyon, Rivermile 58.5 to 56.0 | 0.04% | 3.6 |
| Knights Ferry, Rivermile 54.7 to 53.5 | 0.0% | 7.5 |
| Lovers Leap, Rivermile 53.5 to 51.6 | 97.0% | 2.6 |
| Below Willms Pond, Rivermile 51.6 to 51.1 | 0.0% | 12.0 |
| Horseshoe Road, Rivermile 51.1 to 49.75 | 97.5% | 2.2 |
| Honolulu Bar, Rivermile 49.75 to 48.5 | 0.0% | 7.2 |
| Above Orange Blossom, Rivermile 58.5 to 47.4 | 98.2% | 0.9 |
| Below Orange Blossom, Rivermile 47.4 to 44.9 | 0.0% | 6.8 |
| Total: 13.15 miles | 39.3% | -- |

There are at least six in-stream mine pits in the primary salmonid spawning reach between Goodwin Dam and Riverbank:

- A small pit just upstream of Two-Mile Bar at rivermile 56.9
- Two adjacent small pits near rivermile 53.5, near the Twin Buttes;
- Willm's Pond at rivermile 51.8,
- Button Bush Pond at rivermile 48.2; and
- Oakdale Recreation Pond, which is about one mile long, at rivermile 39.4.

Captured mine pits trap bedload sediment, store large volumes of sand and silt, and pass sediment-starved water downstream where it typically erodes the channel bed and banks to regain its sediment load (Kondolf and others 2001). At the upstream and downstream ends of the pit, the over-steepened bed is an unstable knickpoint, which causes bed erosion such that the pit elongates in both an upstream and downstream direction. On the Stanislaus River, incision has been limited due to the reduction in channel forming flows since the construction of New Melones Dam.

In the areas adjacent to the instream mine pits and other off river mining areas (e.g., Horseshoe Road pond), drag lines were used to excavate the gravel from the active channel and adjacent floodplain which created a relatively wide, channelized ditch that is nearly devoid of spawning and rearing habitat. Approximately 40% of the channel has been dredged between Goodwin Dam and just downstream of the Orange Blossom Bridge at rivermile 44.9. It was not possible to quantify the amount of dredging in the downstream areas using the 1972 CDFG maps, although dredging has clearly occurred throughout much of the lower river.

In the few unmined sections, some of the spawning-sized gravel still remains. For example, in the one-half mile section downstream from Willms Pond, most of the riffles shown in the 1972 CDFG maps still contained substantial amounts of spawning-sized gravel and most were well used by spawning salmon during the mid-1990s (CMC and others 1996). In contrast, there were

fifteen riffles downstream from the Valley Oak Recreational Park that were shown on the 1972 CDFG maps, many of which were probably in mined reaches, but were not evident during the mid-1990s surveys. This suggests that spawning-sized gravel is still being transported from riffle to riffle in the unmined reaches, which helps maintain the suitability of these riffles for spawning and rearing habitat. However, there is little or no gravel recruitment to the isolated riffles that were left in the mined reaches and as a result, most of these riffles provide little or no spawning or rearing habiat.

## LITERATURE CITED

[CDFG] California Department of Fish and Game. 1972. Report to the California State Water Resources Control Board on effects of the New Melones Project on fish and wildlife resources of the Stanislaus River and Sacramento-San Joaquin Delta. Produced by Region 4, Anadromous Fisheries Branch, Bay-Delta Research Study, and Environmental Services Branch.

[CMC] Carl Mesick Consultants, Aquatic Systems Research, and Thomas R. Payne & Associates. 1996. Spawning habitat limitations for fall-run chinook salmon in the Stanislaus River between Goodwin Dam and Riverbank. Report prepared for Neumiller & Beardslee and the Stockton East Water District.

[CMC] Carl Mesick Consultants. 2001. Task 3 pre-project evaluation report, Knights Ferry Gravel Replenishment Project. Final report produced for the CALFED Bay Delta Program and the Stockton East Water District. Revised 20 July 2001, El Dorado, California.

[CMC] Carl Mesick Consultants. 2002a. Task 5 initial post-project evaluation report, Knights Ferry Gravel Replenishment Project. Final report produced for the CALFED Bay Delta Program and the Stockton East Water District. 14 January 2002, El Dorado, California.

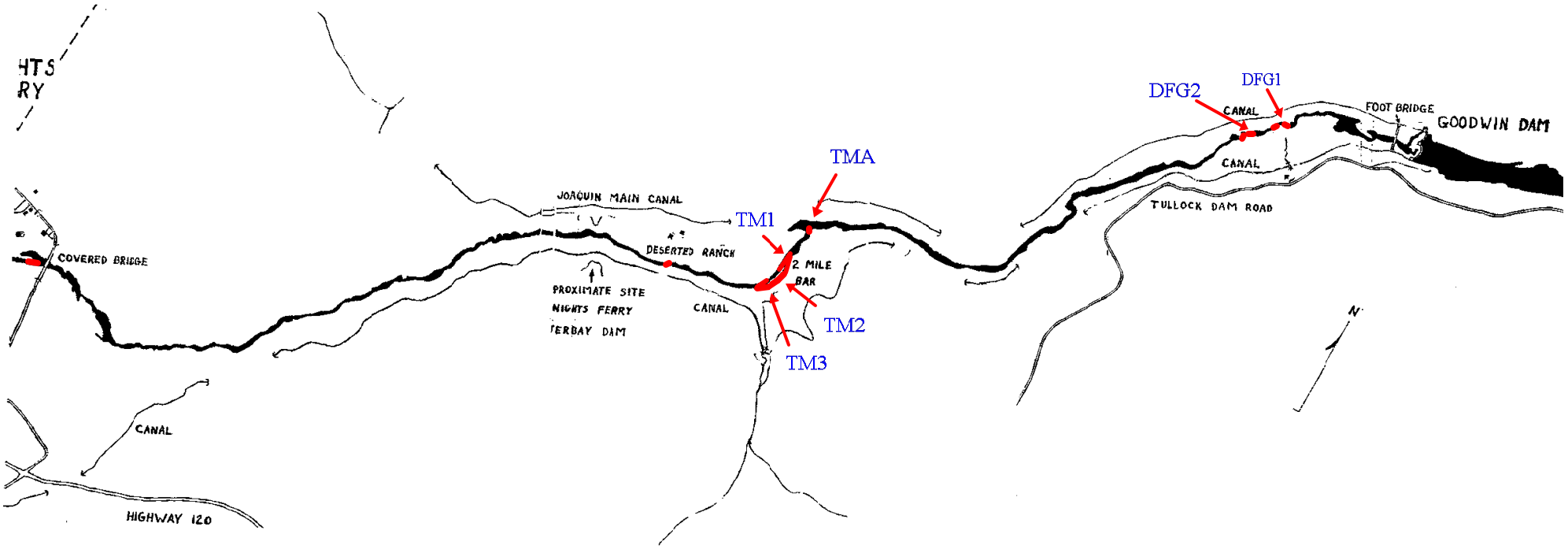
[CMC] Carl Mesick Consultants. 2002b. Task 6 second year post-project evaluation report, fall 2000, Knights Ferry Gravel Replenishment Project. Final report produced for the CALFED Bay Delta Program and the Stockton East Water District. 15 February 2002, El Dorado, California.

Kondolf, G.M, A. Falzone, and K.S. Schneider. 2001. Reconnaissance-level assessment of channel change and spawning habitat on the Stanislaus River below Goodwin Dam. Report prepared for the U.S. Fish and Wildlife Service, Sacramento, CA. 22 March 2001.

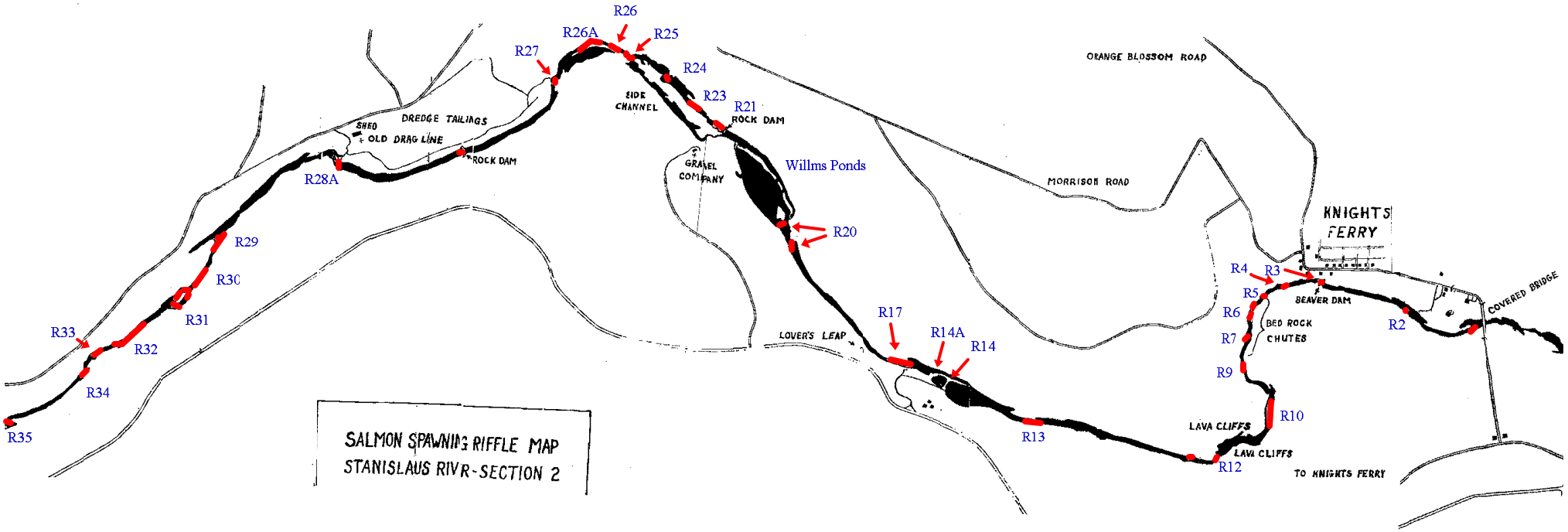
## NOTES

Frymire, P. 2000. Long-term resident of the Stanislaus River corridor, Frymire Road, Knights Ferry, California. Personal communication with Carl Mesick, March 2000.

Map 1. CDFG map of salmon spawning riffles (shown in red) revised 1972 from Goodwin Dam to Knights Ferry. Some riffles are identified with CMC numbering system.

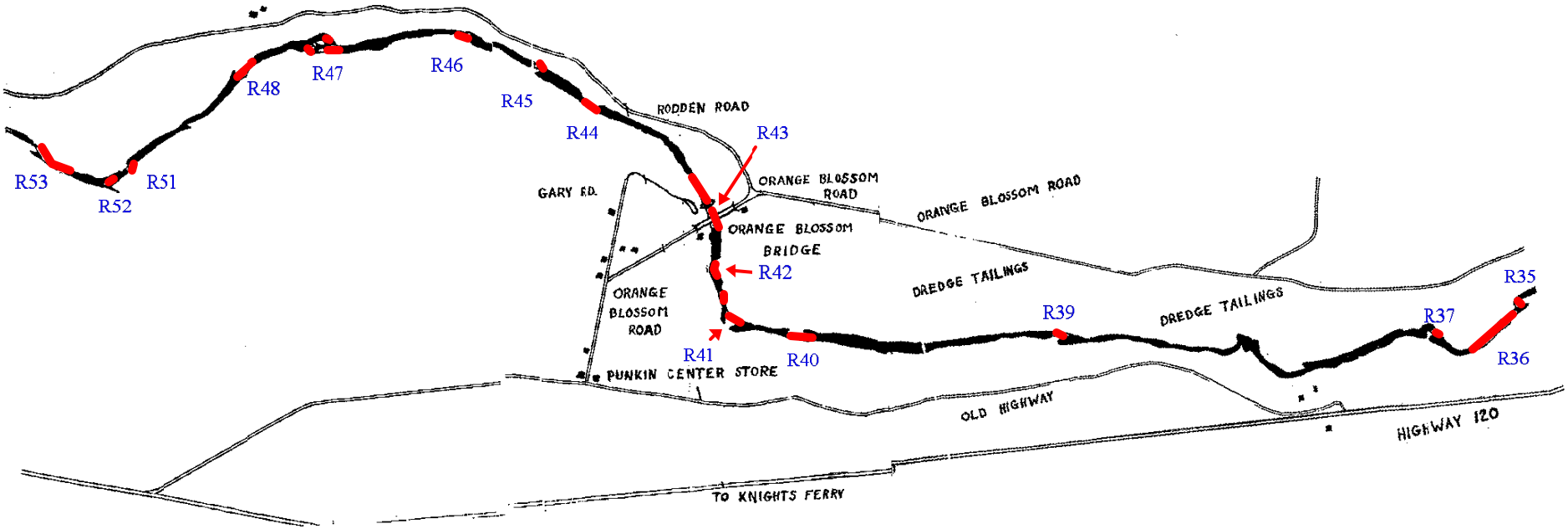


Map 2. CDFG map of salmon spawning riffles (shown in red) revised 1972 from Knights Ferry to Honlulu Bar. Some riffles are identified with CMC numbering system.

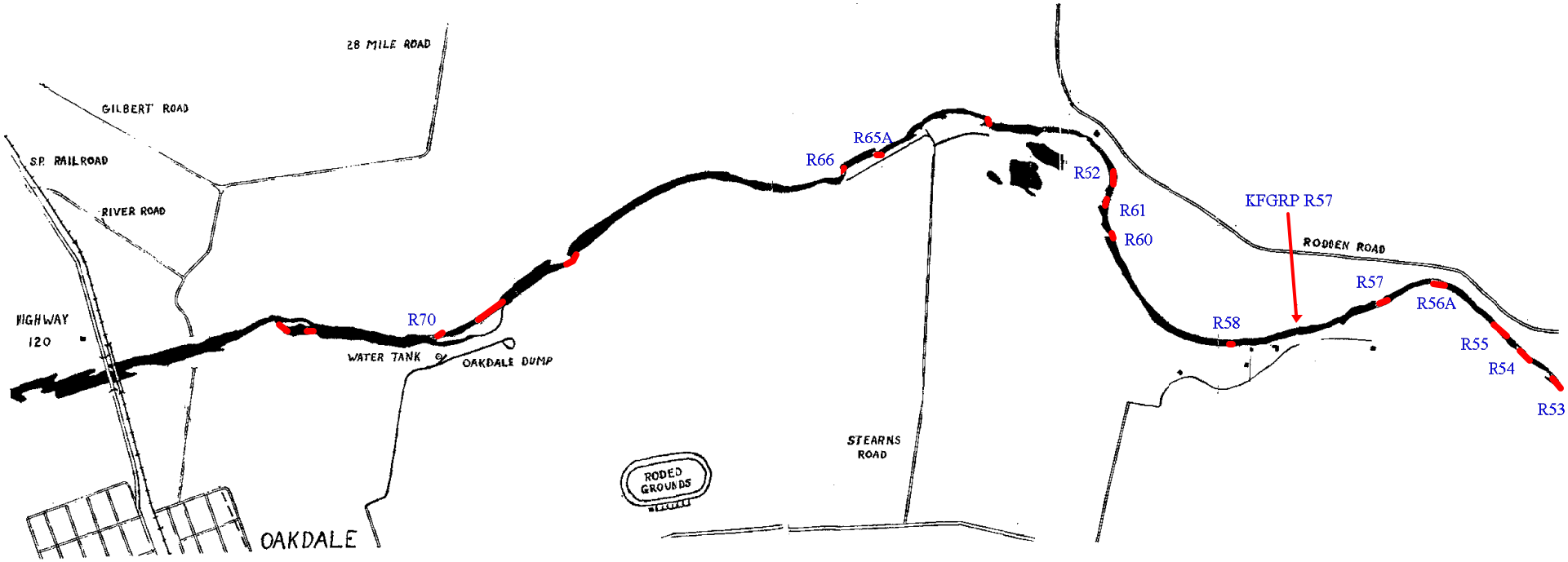


Map 3. CDFG map of salmon spawning riffles (shown in red) revised 1972 from Honlulu Bar to below Orange Blossom Bridge.

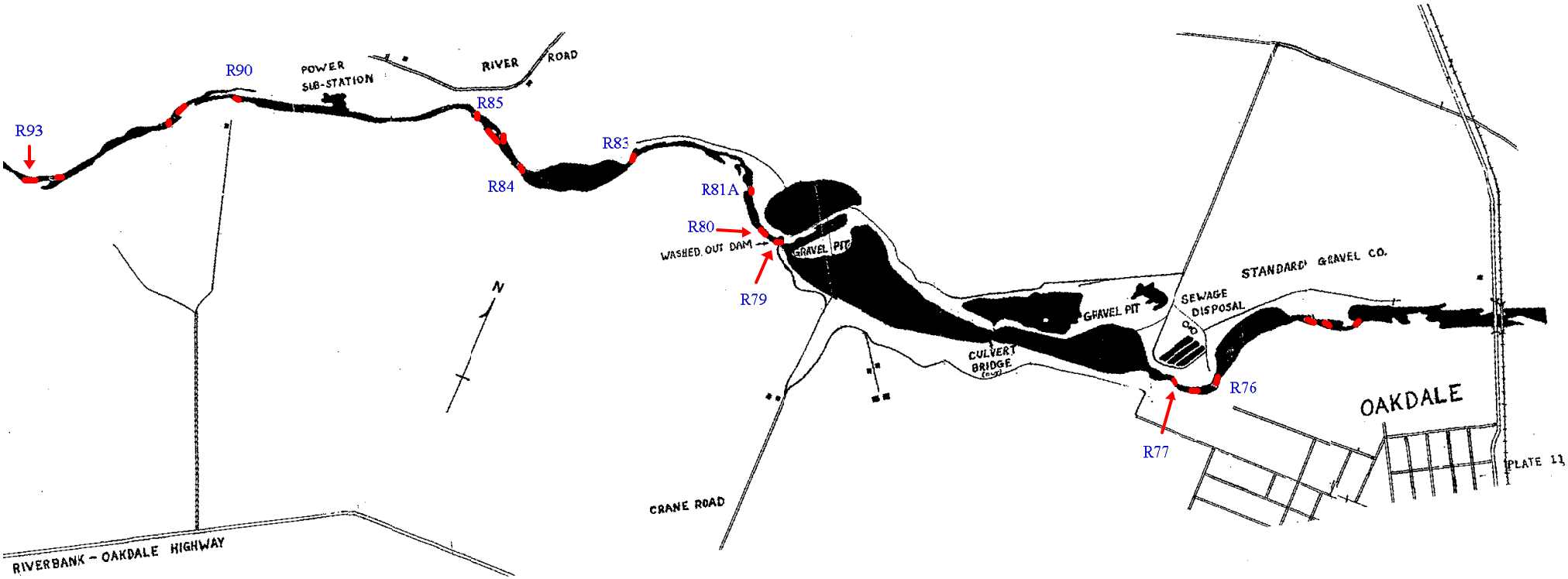
Some riffles are numbered according to the CMC numbering system.



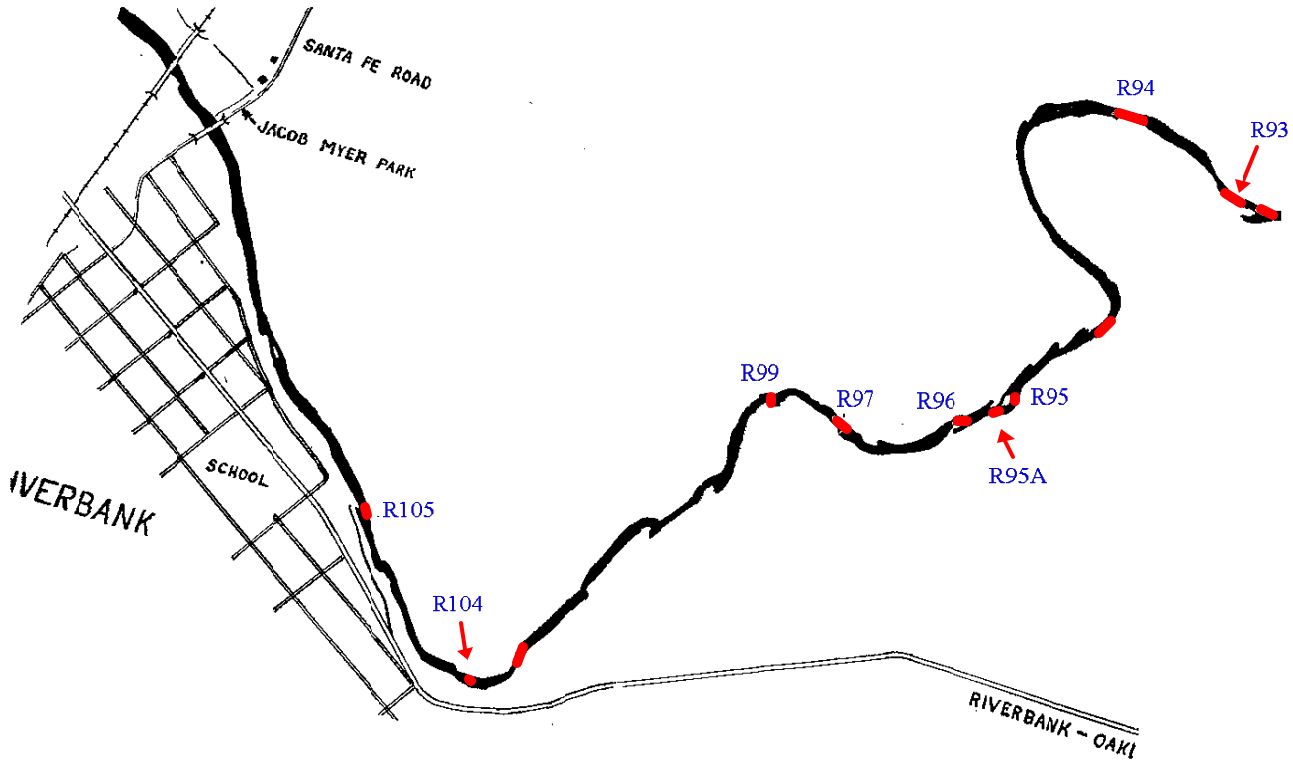
Map 4. CDFG map of salmon spawning riffles (shown in red) revised 1972 from below Orange Blossom Bridge to Hwy 120 Bridge. Some riffles are identified with CMC numbering system.



Map 5. CDFG map of salmon spawning riffles (shown in red) revised 1972 from the Highway 120 Bridge to above Riverbank. Some riffles are identified with CMC numbering system.



Map 6. CDFG map of salmon spawning riffles (shown in red) revised 1972 near Riverbank. Some riffles are identified with CMC numbering system.



# LENGTHS OF SALMON SPAWNING RIFFLES ON STANISLAUS RIVER WHICH ARE PRESENTLY USABLE OR MAY BE RECLAIMED

## Goodwin Dam to Knights Ferry Bridge

| Riffle Number | Length in Feet |
|---|---|
| 1 | 395 |
| 2 | 55 |
| 3 | 55 |
| | 505 |

## Knights Ferry Bridge to Orange Blossom Bridge

| Number | Length in Feet |
|---|---|
| 1 | 65 |
| 2 | 205 |
| 3 | 57 |
| 4 | 270 |
| 5 | 55 |
| 6 | 280 |
| 7 | 55 |
| 8 | 70 |
| 9 | 90 |
| 10 | 300 |
| 11 | 160 |
| 12 | 80 |
| 13 | 450 |
| 14 | 90 |
| 15 | 150 |
| 16 | 280 |
| 17 | 155 |
| 18 | 100 |
| 19 | 120 |
| 20 | 88 |
| *21 | 65/90/130 |
| *22 | 63/100/58/32/104/50 |
| 23 | 145 |
| 24 | 290 |
| 25 | 95 |
| *26 | 265/190 |
| *27 | 30/25 |
| 28 | 35 |
| *29 | 90/120 |
| | 5,097 ft. |

## Orange Blossom Bridge to Oakdale Bridge

| Number | Length in Feet |
|---|---|
| 30 | 200 |
| 31 | 80 |
| *32 | 50/185 |
| 33 | 330 |
| 34 | 50 |
| 35 | 100 |
| *36 | 155/20 |
| 37 | 460 |
| 38 | 90 |
| *39 | 120/25 |
| 40 | 220 |
| 41 | 150 |
| 42 | 280 |
| 43 | 90 |
| 44 | 60 |
| 45 | 80 |
| 46 | 65 |
| 47 | 50 |
| 48 | 75 |
| 49 | 100 |
| 50 | 25 |
| 51 | 40 |
| 52 | 90 |
| 53 | 275 |
| *54 | 65/125 |
| 55 | 50 |
| 56 | 20 |
| 57 | 50 |
| | 3,775 ft. |

## Oakdale Bridge to Riverbank Bridge

| Number | Length in Feet |
|---|---|
| 58 | 35 |
| 59 | 110 |
| 60 | 95 |
| 61 | 235 |
| 62 | 100 |
| 63 | 220 |
| *64 | 70/65 |
| 65 | 30 |
| 66 | 30 |
| 67 | 45 |
| 68 | 220 |
| 69 | 55 |
| 70 | 50 |
| 71 | 30 |
| 72 | 430 |
| 73 | 30 |
| 74 | 470 |
| *75 | 120/50 |
| 76 | 70 |
| 77 | 25 |
| 78 | 65 |
| *79 | 170/30/40 |
| 80 | 50 |
| 81 | 30 |
| 82 | 60 |
| 83 | 50 |
| | 3,080 ft. |

Total of riffle lengths:

Knights Ferry to Riverbank - 11,952 ft.

Goodwin Dam to Riverbank - 12,457 ft.

* Indicates one location but split spawning areas

PLATE C